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USE OF CLOSED BOMB TEST METHODS FOR ASSESSING 81 MM MORTAR PROPELLANT

LESTER SHULMAN

LOUIS BOTTEI

JULY 1960

PICATINNY RESEARCH CENTER
PICATINNY ARSENAL
DOVER, N. J.

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by

Lester Shulman
Lauis Battei

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Picatinny Research Center
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for L. H. ERIKSEN
Chief, Explasives and
Prapellants Labaratary

TABLE OF CONTENTS

OBJECT

To establish a basis for using closed bomb testing in place of flight testing as a means of assessing 81 mm mortar increment propellant.

SUMMARY

The results obtained from 320 closed bomb firings and 280 proof firings of test samples representing 14 production lots of M5 increment propellant for the 81 mm mortar indicate a high degree of correlation, as shown by the statistical "H" test. On the basis of these results, equations relating flight velocities and mortar tube pressures to closed bomb parameters are derived. With these equations, velocities and pressures for the 81 mm mortar can be predicted within ±2.3% and ±4.9%, respectively.

CONCLUSIONS

Based on the results of closed bomb and ballistic tests performed on 14 lots of M5 increment propellant (M9 composition) for the 81 mm mortar, two equations have been derived which can be used to predict with reasonable accuracy the velocities and pressures to be expected in the mortar. These equations can be used for assessing any available 81 mm increment propellant. However, these equations are not applicable if either the composition or the geometry of the lots tested differs by more than 5% from the lots studied in this investigation. This limitation is necessary due to the statistically small number of available samples and the skewness of the distribution curve of the lots used in this study. The 5% limitation does not prohibit the use of the equations for assessing M5 increment propellant since the acceptance requirements of PA–PD–55 (Rev 1) permit only a ±1.5% deviation in composition. For this reason, any propellants acceptable under the above specification should be readily assayed for pressure and velocity characteristics by the equations derived in this investigation.

RECOMMENDATIONS

Since closed bomb testing can greatly expedite the assessment of increment propellant for the 81 mm mortar, and is relatively inexpensive compared to the cost of proof firing, this method should be used together with proof firing tests until sufficient data is acquired to ascertain the validity of the equations derived from the results of this investigation. After sufficient concurrent testing has been completed, only occasional proof firing will be required.

It is recommended that if changes in the composition or geometry of the propellant for the 81 mm mortar are anticipated, the procedures of this investigation be used to establish new equations for evaluating the propellant.

INTRODUCTION

In October 1956 a study was conducted at Picatinny Arsenal on the feasibility of using closed bomb testing instead of proof firing for the acceptance of 60 mm mortar propellant (Ref 4). As a result equations were derived for predicting the ballistic performance on the basis of closed bomb test results. At the conclusion of this investigation, the M8 propellant for the 60 and 81 mm mortars became obsolete and an M9 propellant composition was substituted. Since the experimental procedures and method of analysis were considered to be readily applicable to M9 propellant, a study was begun to evaluate the possibility of accepting this propellant for the 81 mm mortar.

When funds were assigned by OAC for the closed bomb testing of M9 increment propellant for the 81 mm mortar, it was found that current M9 propellant was being accepted according to Addendum 55–1 to PA–PD–55. This specification requires that the propellant be accepted on the basis of tests in the caliber .30 rifle. Since this test method does not relate to the performance of the propellant in the complete round, the data from these tests could not be used for correlation with closed bomb tests. It was found, however, that 14 lots of M5 increments which were in storage had been tested in the 81 mm mortar. The results obtained in this investigation, therefore, are based on the testing of these propellants.

RESULTS

The chemical compositions of the lots tested are shown in Table 1 (p 5). The relative quickness and relative force values and their respective standard deviations are shown in Table 2 (p 6). The results of proof firing tests in the 81 mm mortar tube are given in Table 3 (p 7). On the basis of values shown in the tables, an equation relating the muzzle velocity and closed bomb test values was derived. The equation is:

$$V = 0.82\ RQ - 0.35\ RF + 718.80 \qquad (1)$$

Where:

V = muzzle velocity, fps

RQ = relative quickness, as compared with standard lot 1A–18–43, %

RF = relative force, as compared with standard lot 1A–18–43, %.

A comparison of the calculated velocity values from equation 1 and the actual muzzle velocities is shown in Table 4 (p 8).

In addition to the equation for prediction of velocities, an equation was derived for calculating the 81 mm mortar tube pressures from closed bomb test data (equation 2).

$$P = 34.08\ RQ + 200.95\ RF - 15335 \qquad (2)$$

Where:

P = mortar tube pressure, psi

The calculated pressure values from equation 2 and the actual pressure values are compared in Table 5 (p 9).

DISCUSSION OF RESULTS

In order to determine whether the muzzle velocities and mortar pressures (Table 3) and relative force (Table 2) were from identically distributed populations a rank-sum test ("H' ' test) was performed. The equation used for this test is:

$$H = \frac{12}{N(N+1)}\left(\Sigma\frac{R_i^2}{N_i}\right) - 3(N+1) \qquad (3)$$

Where:

N = total number of test results

N_i = number of test results of each parameter

R_i = rank of any test result in each parameter

The solution of equation 3 for H resulted in a value of 0.128. Comparing this value with table values (5.99) of χ^2 distributions given in Reference 1 proves that at a 95% certainty level there is no significant difference between velocity, pressure, or relative force populations. This conclusion indicates that ballistic and closed bomb data should be related mathematically. The derivation of equations 1 and 2 for predicting muzzle velocity and pressure from closed bomb data was based on a modification of equations 4 and 5 given in Reference 2.

$$\frac{dV}{V_s} = l_a\left[\frac{d(RQ)-d(RF)}{100}\right] + l_f\ \frac{d(RF)}{100}\Big) \qquad (4)$$

and

$$\frac{dP}{P_s} = M_a\left[\frac{d(RQ)-d(RF)}{100}\right] + M_f\left(\frac{d(RF)}{100}\right) \qquad (5)$$

Where:

dV = difference between the muzzle velocities of test and reference lots, in fps

V_s = muzzle velocity of the reference lot, in fps

dP = difference between pressure of test and reference lots in the gun tube, in psi

P_s = pressure of reference lot, in psi

l_a, l_f, M_a, and M_f = Sugot's differential coefficients

(The other terms were previously defined.)

Because the test and reference lots are similar in composition the difference between the relative force values is small. The important closed bomb parameter is the difference between the RQ and RF. Since no data was available for the differential coefficient in the 81 mm mortar, these values were obtained from the experimental data. This was accomplished by listing the test results in descending order of their absolute dP/dt – pressure values. The highest and lowest values in this list were substituted in equations 4 and 5. Since no reference lot had been used in the proof firing of the test lots, a reference standard was selected on the basis of closed bomb test results. Lot 1A–18–43 was selected because the dP/dt – pressure value for this lot is the same as the mean value. All ballistic and closed bomb values were referred to 1A–18–43 as the standard. With these values substituted in equations 4 and 5, the differential coefficients were obtained by solving the two equations simultaneously. The differential coefficients were then substituted in equations 4 and 5 and the equations were simplified into the form shown in equations 1 and 2.

The small differences in the standard deviations of the test lots in Table 2 (p 6) indicate the uniformity of the propellants tested. Since it is estimated that the reproducibility of the instrumentation in measuring relative quickness is within 1%, the contribution of the variability of the 14 lots of propellant tested varies between 0.4 and 1.0%. The variability in the measurement of relative force is estimated at 0.5%, which then gives a range of 0.3 to 1.0% for the variability of the propellant. Since relative quickness depends on geometry, and relative force on composition, it is estimated that the variability in geometry within any of the lots tested is less than 1% and the uniformity of the composition is within 1%.

EXPERIMENTAL PROCEDURE

A charge weight of 11.82 grams of each of the test lots was burned in a closed bomb following the procedures described in Reference 3. These test samples were fired until a total of 20 tests were completed for each of the test lots. From the dP/dt vs P traces of these tests, the average dP/dt values at approximately 5000 psi and the average maximum pressures were determined. The closed bomb data was then combined with the proof firing data by a method similar to that used in Reference 4, and equations relating the muzzle velocities and mortar tube pressures with closed bomb test results were obtained.

REFERENCES

1. W. Dixon and F. Massey, *Introduction to Statistical Analysis*, McGraw-Hill, 1957

2. E. I. du Pont de Nemours and Company, *Standard Procedures for Testing Smokeless Powder in Closed Bombs*, Memorandum Report No. 27, April 1942

3. A. O. Pallingston and M. Weinstein, *Method of Calculation of Interior Ballistic Properties of Propellants from Closed Bomb Data*, Picatinny Arsenal Technical Report 2005, June 1954

4. Lester Shulman, *Use of Closed Bomb Data for the Assessment of 60 mm Mortar Increment Propellant*, Picatinny Arsenal Technical Report 2350, October 1956

TABLE 1

Composition (%) and Dimensions of M9 Propellant

Lot	Nitrocellulose (13.25% N)	Nitroglycerin	Potassium Nitrate	Ethyl Centralite	Length, in.	Diam, in.
1A-18-39	58.33	39.72	1.28	0.67	.0095	.0600
1A-18-40	58.64	39.48	1.17	0.71	.0093	.0589
1A-18-41	57.69	40.33	1.25	0.73	.0093	.0597
1A-18-42	58.34	39.62	1.34	0.70	.0096	.0597
1A-18-43	58.71	39.34	1.25	0.70	.0095	.0600
1A-18-44	57.71	40.10	1.48	0.71	.0094	.0594
1A-18-45	58.59	39.35	1.35	0.71	.0093	.0594
1A-18-46	57.81	40.05	1.39	0.75	.0097	.0597
1A-18-47	58.77	39.30	1.21	0.72	.0090	.0598
1A-18-48	58.66	39.45	1.18	0.71	.0093	.0592
1A-18-49	58.67	39.28	1.20	0.85	.0085	.0612
1A-18-50	58.11	39.72	1.37	0.80	.0086	.0596
1A-18-53	58.17	39.63	1.43	0.77	.0094	.0589
1A-18-54	57.43	40.50	1.31	0.76	.0095	.0597

TABLE 2

Summary of Closed Bomb Results

Lot No.	No. of Tests	Relative Quickness, %	Std Dev	Relative Force, %	Std Dev
1A-18-39	20	97.63	1.51	100.12	0.78
1A-18-40	20	101.52	1.60	100.87	1.05
1A-18-41	20	99.18	1.60	100.34	0.74
1A-18-42	20	101.05	1.52	100.79	1.26
1A-18-43	20	100.00	2.03	100.00	0.92
1A-18-44	20	100.70	1.85	100.20	0.86
1A-18-45	20	101.08	1.46	99.91	1.14
1A-18-46	20	99.54	1.73	99.68	1.05
1A-18-47	20	102.08	1.36	100.88	0.82
1A-18-48	20	100.84	1.75	99.89	1.04
1A-18-49	20	99.75	1.79	100.23	1.12
1A-18-50	20	100.54	1.79	99.81	0.95
1A-18-53	20	98.91	1.46	99.80	1.48
1A-18-54	20	99.41	1.62	99.77	1.43

TABLE 3

Summary of Ballistic Firing Results

Lot No.	No. of Tests	Muzzle Velocity, fps	Std Dev	Avg Pressure, psi	Std Dev
1A–18–39	10	764.3	3.3	8110	150
1A–18–40	9	757.9	1.5	8395	176
1A–18–41	10	763.5	2.7	8550	195
1A–18–42	10	768.0	4.2	8635	229
1A–18–43	10	766.3	2.2	8245	104
1A–18–44	10	769.0	2.4	8340	102
1A–18–45	9	764.3	1.2	8385	154
1A–18–46	10	769.5	4.2	8390	86
1A–18–47	10	767.7	3.6	8410	132
1A–18–48	10	769.7	2.7	8480	133
1A–18–49	10	751.2	11.9	8100	114
1A–18–50	9	768.3	5.2	8340	117
1A–18–53	10	761.2	9.6	8285	133
1A–18–54	10	772.1	2.3	8525	161

TABLE 4

Comparison of Actual and Calculated Velocities

Sample	Relative Quickness, %	Relative Force, %	Calc Velocity, fps	Actual Velocity, fps	Diff, fps	Diff, %
47	102.08	100.88	767.7	767.7	0	0
45	101.08	99.91	767.2	764.3	+ 2.9	0.38
48	100.84	99.89	767.0	769.7	− 2.7	0.35
53	98.91	99.80	765.5	761.2	+ 4.3	0.56
50	100.54	99.81	766.8	768.3	− 1.5	0.20
40	101.52	100.87	767.2	762.7	+ 4.5	0.59
44	100.70	100.20	766.8	769.0	− 2.2	0.29
42	101.05	100.79	766.9	768.0	− 1.1	0.14
43	100.00	100.00	766.3	766.3	0	0
46	99.54	99.68	766.0	769.5	− 3.5	0.45
54	99.41	99.77	765.9	772.1	− 6.2	0.80
49	99.75	100.23	766.0	751.2	+14.8	1.97
41	99.18	100.34	764.7	763.5	+ 1.2	0.16
39	97.63	100.12	764.3	764.3	0	0

TABLE 5

Comparison of Actual and Calculated Pressures

Sample	Relative Quickness, %	Relative Force, %	Calc Pressure, psi	Actual Pressure, psi	Diff, psi	Diff, %
47	102.08	100.88	8416	8410	+ 6	0
45	101.08	99.91	8187	8385	−198	2.4
48	100.84	99.89	8175	8480	−305	3.6
53	98.91	99.80	8090	8285	−195	2.4
50	100.54	99.81	8148	8340	−192	2.3
40	101.52	100.87	8395	8395	0	0
44	100.70	100.20	8232	8340	−108	1.3
42	101.05	100.79	8363	8635	−272	3.1
43	100.00	100.00	8168	8245	− 77	0.9
46	99.54	99.68	8088	8390	−302	3.6
54	99.41	99.77	8102	8525	−423	4.9
49	99.75	100.23	8205	8100	+105	1.3
41	99.18	100.34	8208	8550	−342	4.0
39	97.63	100.12	8110	8110	0	0

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